



Name \_\_\_\_\_ Date \_\_\_\_\_ Hour \_\_\_\_\_

### What is causing global warming?

Earth's average temperature has been increasing over the last century. Temperature is an indicator of energy, so the increase in temperature tells us that Earth's energy balance is changing. Inside the core of the Earth, it is very hot, but on its own, the surface of the Earth is well below zero. The primary energy source that maintains Earth's surface temperature at a comfortable level for life is light energy from the Sun. Many of Earth's systems play a role in how the Earth absorbs energy from sunlight and how much of that energy escapes (reflected or emitted) back into space. However, the atmosphere plays the most significant role in maintaining Earth's energy balance. So, the fact that Earth is warming suggests that there has been a change in its atmosphere.

### What molecules are in Earth's atmosphere?

The atmosphere is made up of gas molecules. The most abundant molecule is nitrogen ( $N_2$ ), which makes up about 78% of air. Oxygen ( $O_2$ ) is the second most abundant gas at about 21%. Argon (Ar) is the third most abundant gas at 0.93%. There are also trace amounts of carbon dioxide ( $CO_2$ ), neon (Ne), helium (He), methane ( $CH_4$ ), krypton (Kr), hydrogen ( $H_2$ ), nitrous oxide ( $N_2O$ ), xenon (Xe), ozone ( $O_3$ ), iodine ( $I_2$ ), carbon monoxide (CO), and ammonia ( $NH_3$ ). The atmosphere also contains water vapor ( $H_2O$ ), but the amount varies depending on temperature and altitude.

### Which molecules regulate Earth's energy balance?

The molecules in Earth's atmosphere allow visible light from the Sun to pass through. The Earth absorbs this energy and then releases infrared radiation (heat) back into space. However, some of the molecules in the atmosphere absorb some of the infrared radiation (heat) leaving the Earth. These gases are called greenhouse gases since they trap heat in a similar way that a transparent glass greenhouse traps heat inside. Greenhouse gases include carbon dioxide, methane, ozone, nitrous oxide, and water vapor. Greenhouse gases, therefore, play a key role in regulating Earth's energy balance. This process is called the greenhouse effect.

You will use a simulation to investigate Earth's atmosphere.

### Introduction to the Greenhouse Effect Simulation

Go to the PhET Greenhouse Effect webpage: <https://phet.colorado.edu/en/simulations/greenhouse-effect>.

Press the **play button** on the screen to open up the simulation. Choose **Photons**. On the bottom right-hand side of the screen, **unselect Cloud** if it is selected. Click the **Start Sunlight** button and observe what happens.

1. How is visible light from the Sun represented? Explain what the icons mean and how they move.
2. How is infrared radiation given off by the Earth represented? Explain what the icons mean and how they move.



**Part A. Effect of Greenhouse Gas Concentration**

- A. Click the **orange reset button** to start over. Move the Greenhouse Gas Concentration slider down to **None**. Check the box next to **Energy Balance**. Click **Start Sunlight**. Observe the simulation for one minute. Complete the first row of the table below.
- B. Click the **orange reset button** to start over. Move the Greenhouse Gas Concentration slider halfway up, check the box next to **Energy Balance**, and click **Start Sunlight**. Observe the simulation for one minute. Complete the second row of the table below.
- C. Click the **orange reset button**. Move the slider up to **Lots**. Check the box next to the **Energy Balance box** and click **Start Sunlight**. Observe the simulation for one minute. Complete the last row of the data table.

3. Complete the data table to show the relationship between greenhouse gases and Earth’s temperature.

Greenhouse gas concentration	Surface Temperature	Describe the energy balance (incoming versus outgoing)
None		
Middle		
Lots		

- 4. Explain the patterns. How does changing the amount of greenhouse gases affect Earth’s energy balance?

**Part B. Simulating Earth’s Atmosphere Over Time**

- D. Click the **orange reset button**. Click the calendar icon at the bottom of the Greenhouse Gas Concentration box.
- E. Click **2020**. Record the greenhouse gas concentrations and what the environment looks like in the data table.
- F. Click **Start Sunlight** and record the temperature in the data table below once it stops changing.
- G. Repeat **Steps A - F** for **1950, 1750, and the Ice Age**, and then use the results to write an explanation.

5. Record data from the simulation of Earth’s atmosphere over time and write an explanation.

Time Period	Greenhouse Gas Concentration	Observations about environment	Temp	How have human activities altered Earth’s energy balance?
2020	CO <sub>2</sub>			
	CH <sub>4</sub>			
	N <sub>2</sub> O			
1950	CO <sub>2</sub>			
	CH <sub>4</sub>			
	N <sub>2</sub> O			
1750	CO <sub>2</sub>			
	CH <sub>4</sub>			
	N <sub>2</sub> O			
Ice Age	CO <sub>2</sub>			



### Developing a model

In Activity 2, you learned about how humans use fossil fuels as an energy source for devices. You investigated ethanol burning and discovered that when any organic molecule burns, it reacts with oxygen molecules in the air to produce carbon dioxide and water molecules. Both carbon dioxide and water molecules are greenhouse gases. However, water molecules don't stay in the atmosphere long because they condense into clouds and then fall back to the Earth as rain or snow (the water cycle). Adding extra carbon dioxide to the atmosphere is a problem because those molecules can stay in the atmosphere for years (even centuries) before they are removed from the atmosphere by photosynthesis or dissolve in the ocean. Scientists now understand that the leading cause of global warming over the last century is human activities that have increased the amount of greenhouse gases (especially carbon dioxide) in Earth's atmosphere.

Make a model in the space below that explains what is causing global warming. Make sure that you include the following:

- Visible light from the Sun
- Infrared light (heat) radiating from the Earth
- Earth's atmosphere
- Burning fuels
- Carbon dioxide
- Earth's surface temperature (or Earth's energy balance)

It may be helpful to draw two different models: one representing before humans began burning large amounts of fossil fuels and one representing current conditions. Make sure to label the arrows and write a short description (1-2 sentences) below your model.